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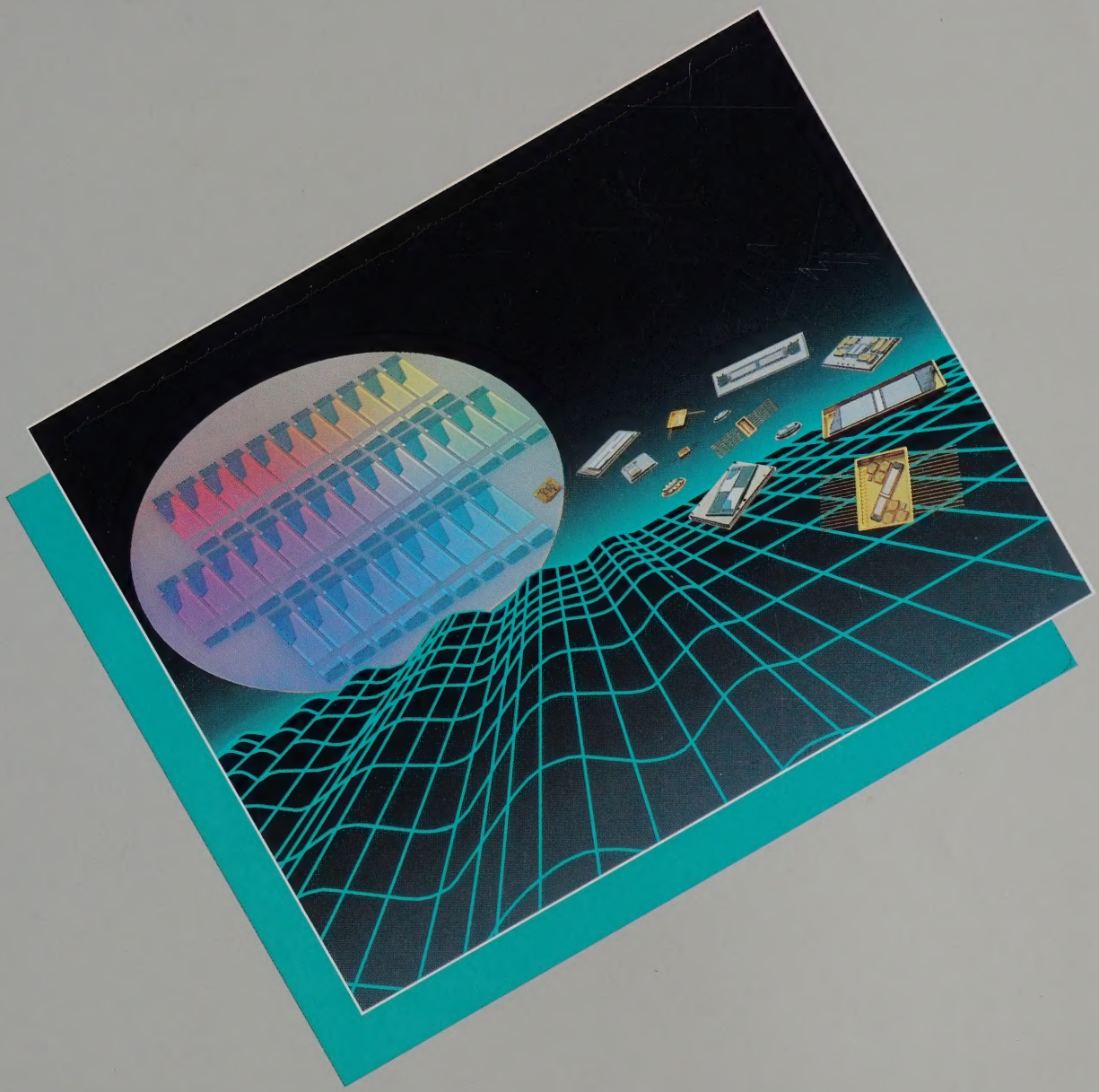


SAW FILTERS

Transversal Filter Operation

A surface acoustic wave (SAW) transversal filter usually consists of two thin film aluminum transducers deposited on the surface of a piezoelectric substrate material. The simplest transducer is made up of interdigital electrodes of alternating polarity, spaced at ½ or ¼ wavelength of the desired operating frequency. Since the surface wave velocity is 10^{-5} slower than the speed of light, an acoustic wavelength is much smaller than its electromagnetic counterpart. This results in the SAW's unique ability to incorporate an incredible amount of signal processing or delay in a very small volume.

The basic SAW transducer is a bidirectional radiator. That is, half of the power is directed toward the output transducer while the other half is radiated toward the end of the crystal and is lost. By reciprocity, only half of the intercepted acoustic energy at the output is reconverted to electrical energy; hence the inherent 6 dB loss associated with this structure. (Refer to Figure 1.) Numerous second-order effects raise the insertion loss of practical filters to 15 dB - 30 dB.

The transducer is apodized or weighted by changing the relative lengths of the fingers. This technique is used to shape the frequency response and improve rejection. Thus, filter performance is rigidly constrained by inherently repeatable photolithographic techniques.

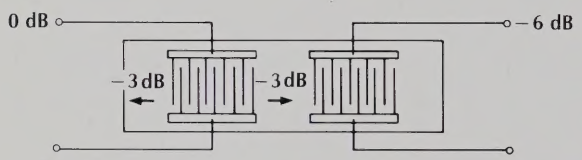


Figure 1. Two-Transducer Transversal Filter Structure

In contrast to the transversal filter, the resonator filter is a standing wave device using reflective arrays to trap the acoustic energy within a high Q resonant cavity. (See Figure 2.) Various methods are used to couple energy from one cavity to another with each cavity representing one attenuation pole. Since the reflectors direct all of the energy to the output, the resonator filter exhibits extremely low losses (1.5 dB - 5.5 dB) even at very narrow bandwidths.

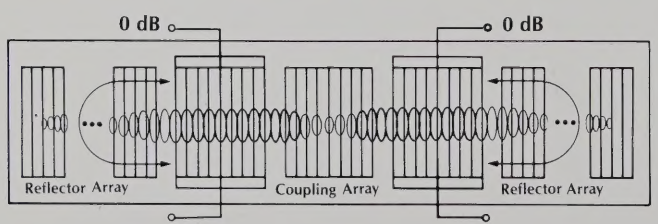
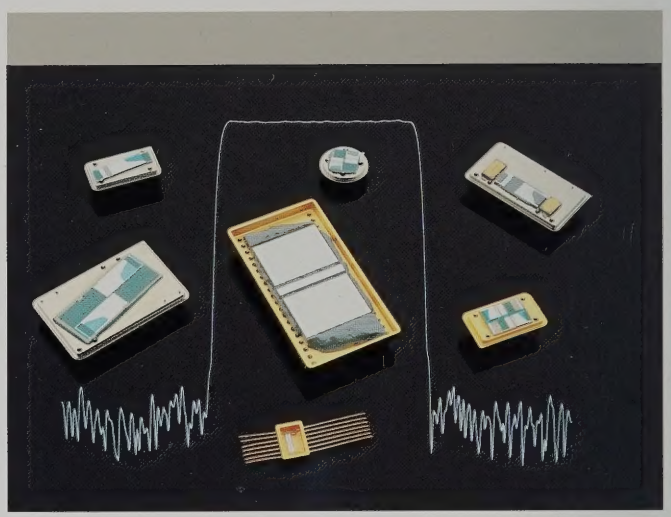


Figure 2. Two-Pole Resonator Filter Structure

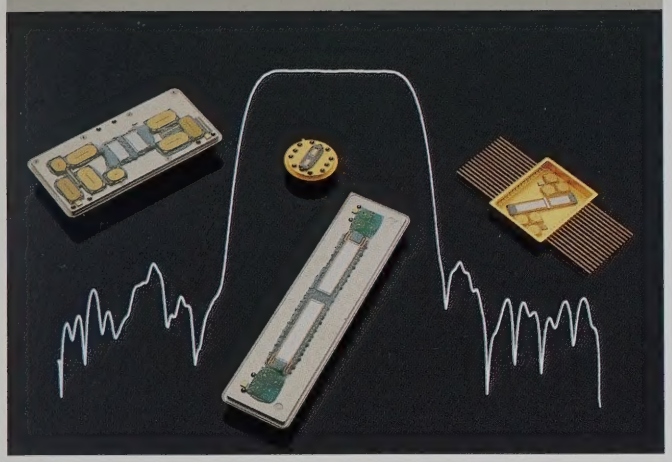


Bidirectional Filters

This class of filters comprises the most widely used application of SAW technology. Sawtek has designed and manufactured many thousands of state-of-the-art bandpass filters for the military and high-performance commercial marketplace.

The wide frequency range of operation (10 MHz - 1600 MHz) is bounded on the high end by submicron electrode geometries and on the low end by overall device size, which becomes impractically large and expensive in comparison to other technologies.

SAW filters are indispensable in applications calling for steep skirts, linear phase and low amplitude ripple. The unique ability to independently specify amplitude and group delay predistortion has been widely used in CATV products to correct for various systems distortions. The inherent reproducibility of these devices makes them ideally suited for phase coherent systems that require two or more channels to closely track in amplitude and phase.



Low-Loss Filters

Sawtek produces high-performance low-loss filters for those applications where system noise figure or dynamic range cannot accommodate the higher loss typical of bidirectional SAW filters. Sawtek's low-loss filters retain the inherent advantages of bidirectional filters while featuring low-loss and excellent triple-transit suppression, making them ideal for front-end or pre-selector type applications.

Although Sawtek is able to implement numerous low-loss configurations, the three-phase unidirectional device offers the highest performance of all currently available techniques. This low loss/high performance is achieved at the expense of a more complex multi-level fabrication process and requires the use of a relatively complicated matching and phasing network to achieve unidirectionality. As a result, most Sawtek low-loss filters are supplied with our unique integrated spiral matching components inside the hermetically sealed filter package. This virtually eliminates interface problems for the customer while providing superior RF feedthrough suppression and temperature stability.

An example of the more complex three-phase unidirectional transducer is shown in Figure 3. It is able to launch the acoustic beam in only one direction and reconvert all of the acoustic energy at the output. The result is a much lower insertion loss (4 dB - 10 dB) and a virtual elimination of regenerated waves which cause triple transit.

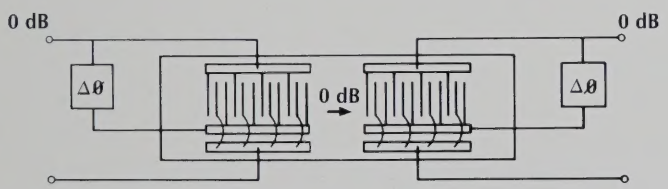


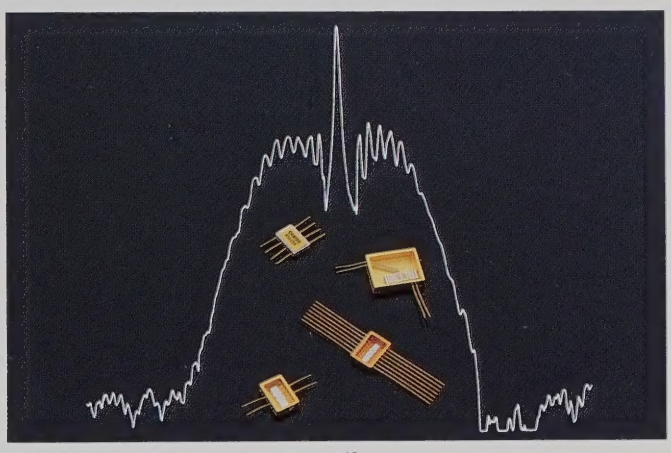
Figure 3. Unidirectional Transducer Filter Structure

Resonator Filters

For narrow bandwidth applications, SAW resonator filters can provide a unique combination of high frequency operation, superior rejection and extremely low loss. These filters are the SAW counterparts of crystal filters, providing extremely sharp filter skirts and rejection bandwidths that are only possible in high Q resonant devices. Excellent temperature stability is achieved by using quartz substrates.

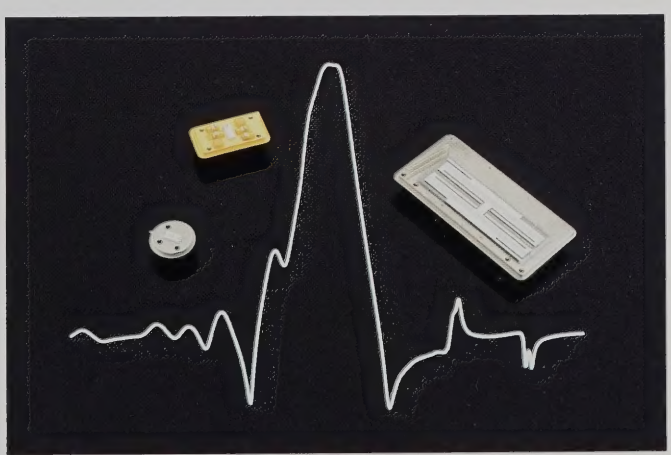
Sawtek has developed two types of resonator filters in order to provide optimum performance:

- In-Line Coupled (ILC) Resonator Filters
- Wave Guide Coupled (WGC) Resonator Filters



Examples of the ILC Resonator Filter

The ILC filter is a two-pole building block. It combines the widest bandwidth available in resonator filters, improved out-of-band rejection by virtue of transversal weighting and the lowest loss of any existing SAW device.



Examples of the WGC Resonator Filter

The WGC filter is a four-pole building block. This filter combines transverse acoustic coupling and electrical coupling to minimize transducer flyback. The WGC filter features fourth-order chebychev rejection characteristics with a minimum of external components.

Refer to Table II for the specific performance parameters of bidirectional filters, low-loss filters, and resonator filters.

Definitions

Bulk Modes
Spurious time and frequency responses caused by acoustic energy that propagates through the bulk of the substrate rather than on its surface. Their detrimental effects are minimized by proper design and manufacturing techniques.

Fractional Bandwidth
The 3 dB bandwidth divided by the center frequency expressed as a percent. This key parameter is used to determine the optimum substrate material. (See Table I.)

Harmonic Design
A technique in which the harmonic image is actually used as the desired filter response. This approach is most commonly used in the design of narrow fractional bandwidth ($<0.5\%$) devices to minimize the effects of overcoupling.

Harmonic Response
A spurious image of the desired frequency response caused by the synchronous finger pattern of the SAW transducer. This image may occur at 2 f_o or 3 f_o, or other distinct frequency, depending on the design technique used.

Internal vs. External Matching
If a specific VSWR is desired, the capacitative SAW transducers must be impedance matched. A simple one or two element matching network may be placed outside the hermetic SAW package to minimize cost or inside the package to minimize interface difficulties.

RF Feedthrough
That portion of the input signal that is capacitatively or inductively coupled to the output without being converted to acoustical energy. Since it essentially travels at the speed of light, it appears in the time domain as a spurious signal at time zero, and in the frequency domain as periodic amplitude ripple and degraded ultimate rejection.

Shape Factor
The ratio of the rejection bandwidth to the passband width. A filter becomes more rectangular as the shape factor approaches 1.0:1.

Transition Bandwidth
The distance in KHz required for the filter response to roll-off from the passband (-3 dB) to the stopband (-40 dB). As this transition width becomes smaller, the resulting filter becomes longer.

Triple Transit
A time domain spurious reflection caused by a regenerated acoustic wave between the two transducers. The effects of triple transit are seen as periodic ripple in the amplitude, phase and group delay versus frequency.

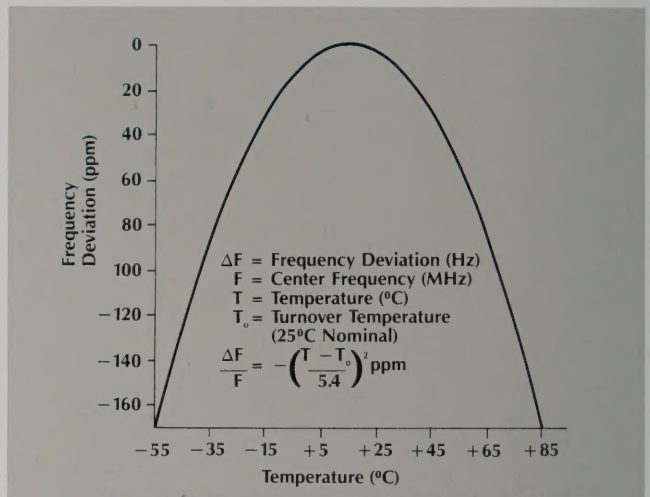


Figure 4. Frequency versus Temperature Curve of an ST-Cut Quartz SAW Device

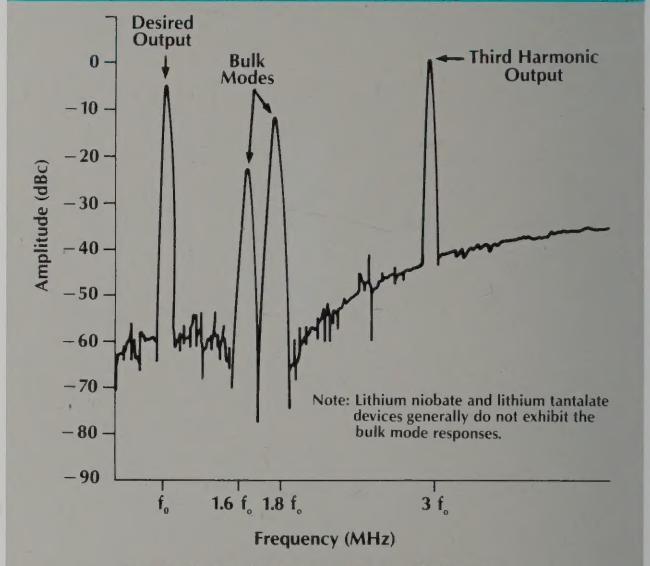


Figure 5. Typical Frequency of Quartz Transversal Filter

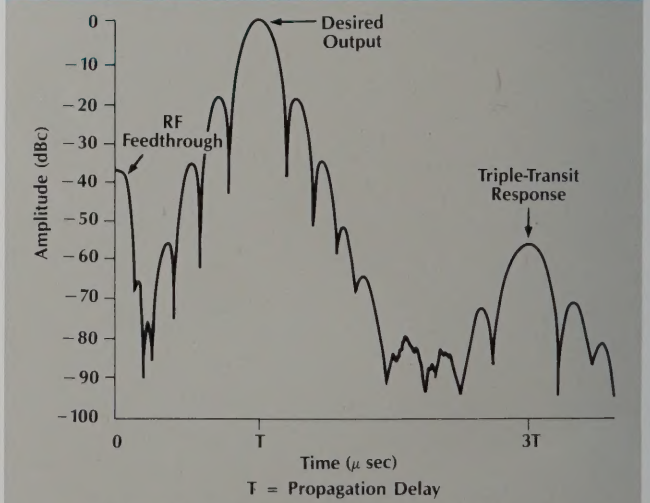


Figure 6. Typical Time Domain Spectrum of Transversal Filter

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At Sawtek, innovative engineering, state-of-the-art manufacturing techniques, and consistent product reliability are well integrated to assure that our customers receive the high-performance SAW components their applications demand. This careful balance of design and manufacturing expertise has established us as the industry's leading supplier of SAW filters.

Sawtek owns and operates its own ultramodern manufacturing facility, complete with a photomask pattern generation machine to ensure rapid turnaround of both development and production activities. Coupled with a vast archive of existing filter designs, our highly accurate and efficient design software enables us to provide the most aggressive quote possible. At the same time, our computer design and analysis capability assures that the specified filter will perform as required in the customer's system thus minimizing the risk normally associated with development activities.

The complex interdependencies of SAW filter parameters require total engineering support. Therefore, our highly trained engineering and technical sales staff is always available to assist you. For each filter development inquiry we receive, we prepare a preliminary design and analysis as well as a detailed technical proposal. This proposal includes comments, exceptions and design trade-offs that will maximize the SAW's utility in your system.

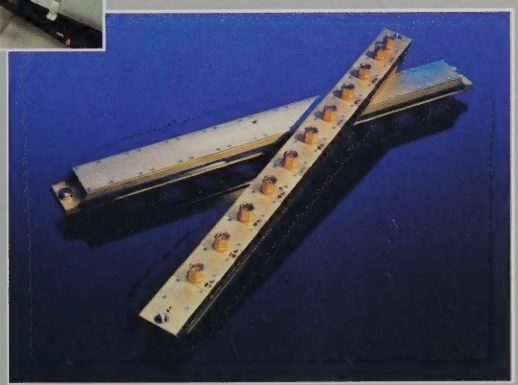
Sawtek filters offer a wide range of operating frequencies — 10 MHz up to nearly 2 GHz. These filters are in our current design inventory and, therefore, can be readily produced for high-volume programs.

The products presented in this brochure represent Sawtek's most established technology . . . SAW filters. Included in Sawtek's selection of filters are:

- SAW Bidirectional Filters
- SAW Low-Loss Filters
- SAW Resonator Filters

In addition to these discrete components, Sawtek designs and manufactures custom assemblies that incorporate SAW filters. These include filter banks and switchable filter modules with adjustable gain.

Automated Assembly Station



10-Channel Filter Bank

Material	Approxmiate Surface Wave Velocity	Temperature Dependency	Optimum Fractional Bandwidth for each Material
ST Quartz	0.124 in/μsec	(See Figure 4.)	0.1% to 5%
Lithium Tantalate	0.129 in/μsec	−23 ppm/°C	4% to 9%
YZ Lithium Niobate	0.134 in/μsec	−94 ppm/°C	7% to 30%
128° Lithium Niobate	0.153 in/μsec	−72 ppm/°C	15% to 65%

Parameter	Bidirectional Bandpass Filter	Low-Loss Bandpass Filter	ILC Resonator Filter	WGC Resonator Filter
Frequency	10 - 1600 MHz	10 - 500 MHz	50 - 1250 MHz	50 - 1250 MHz
Fractional Bandwidth	0.1 to 67%	0.1 to 20%	0.02 to 0.2%	0.02 to 0.1%
Transition Bandwidth	0.200 MHz (min.)	0.200 MHz (min.)	—	—
Insertion Loss	10 - 35 dB	4 - 10 dB	1.5 - 5.5 dB	2.5 - 7.0 dB
Near-In Rejection	35 - 60 dB	35 - 50 dB	10 - 20 dB	35 - 40 dB
Ultimate Rejection	40 - 70 dB	40 - 60 dB	50 - 60 dB	45 - 60 dB
Shape Factor	1.15 - 4.0	1.6 - 4.0	**	2.5 typical
Amplitude Ripple	0.1 - 1.0 dB	0.1 - 0.6 dB	0.1 - 1.0 dB	0.1 - 1.0 dB
Phase Ripple	1 - 10 degrees	1 - 5 degrees	3 - 10 degrees	3 - 10 degrees
Group Delay Ripple	10 - 250 nsec	10 - 100 nsec	100 - 300 nsec	100 - 300 nsec
Triple-Transit Suppression	30 - 60 dB	40 - 60 dB	—	—
Temperature Dependence	See Table I.	See Table I.	−42 ppm/0° to 50°C −104 ppm/−20° to 70°C −219 ppm/−54° to 85°C	−42 ppm/0° to 50°C −104 ppm/−20° to 70°C −219 ppm/−54° to 85°C
**Consult factory. Generally the 40 dB bandwidth is a function of center frequency: BW40 $\cong$ 0.06 x f_o				

FOR MORE INFORMATION

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